LEAST MEAN POWER CONSUMPTION IN TELECOMMUNICATIONS SYSTEMS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to telecommunication networks, and more particularly to dynamic power adjustment in telecommunications network power management.

Background Description

Generally, a telecommunications network links together distributed communications equipment such as telephones, facsimile machines, modems, and the like which all may be located on a customer's premises. In a typical telecommunications network such as a telephone network or plain old telephone service (POTS), a central network communicates with each customer's premises through an access point. The access point normally supplies power to any connected communications equipment at the particular customer's premises. The level of power supplied is typically set for the maximum rated load for the access point, i.e., the largest number of telecommunications devices, e.g., telephones, that are to be allowed to be in simultaneous use. Customer premises include, for example, an office, business location, or residential home.

Further, a typical telephone uses much more power off-hook than on-hook. So, an access point providing power to a multiextension home rated to provide power for simultaneous use by 4 phones may brown out when 5 are off-hook simultaneously and

so forth. However, when only a single phone is off-hook, that same access point is providing much more power than is necessary, all of which is wasted.

Thus, there is a need for a telecommunications system wherein power provided to connected customer equipment is managed dynamically to minimize wasted power.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a diagram of a telecommunications network including at least one customer premises network according to an embodiment of the invention;
FIG. 2 shows a diagram of a programmable access point for interfacing a communications network in accordance with an embodiment;
FIGS. 3-6 show an exemplary control algorithm of comparator and control logic for current level/drive current control in accordance with an embodiment;
FIG. 7 shows an example of operating limits for the output of a POTS line driver used in a programmable access point according to FIG. 2; and
FIG. 8 shows an example of the step increment test as another embodiment for accessing operating limits.

DETAILED DESCRIPTION OF EMBODIMENTS

Turning now to the drawings and more particularly FIG. 1, a general communications network 100 is shown, such as a telephone network.

Network 101 is coupled to an access point 110 within a customer premises network 105. The access point 110 is coupled to customer premise equipment 112 which consists of telephones 113 and 114, a fax machine 115, a computer terminal 116, and a server 117. The customer premise equipment 112 is shown located in customer premises 111 such as a residence, a suite, a building, or group of buildings as in a campus. Network 101 is further coupled to an access point 120 within another customer premises network 106. Access point 120 is coupled to customer premise

equipment 122 which consists of a server 123, a database 124, and a workstation 125. Customer premise equipment 122 is shown located in customer premises 121. It is understood that network 101 can be connected to further access points as indicated by the ellipsis shown in FIG. 1.

Customer premise equipment, also referred to as customer equipment devices, 112 and 122 each show, by way of example, one possible set of devices at a customer's premises, but other configurations are possible. The coupling between each of the customer premise equipment devices and their respective access points and between the access points and the network 101 may each be any form of connection permitting communications such as, but not limited to, wired and wireless connections (e.g. twisted copper pairs, fiber optic cables, telephone cables, or any radio frequency-based approach including, for example, cellular telephonic connection).

It will be appreciated that this invention is applicable to one or simultaneously to a multiplicity of customer premises networks as described herein. Network 101 allows communication between devices located at different customer premises. By way of example, network 101 will allow computer terminal 116 to communicate with database 124. To do this, computer terminal 116 initiates communication through access point 110 to network 101. Network 101 then routes the communication through access point 120 to the database 124. In order to operate, some of the devices coupled to access points 110 and 120 require power to be supplied. In an embodiment, required power is suppled by the access points 110 and 120. By way of example, both telephones 113 and 114 require power to function and this power is delivered from access point 110 over the connecting communication line.

FIG. 2 shows a general schematic of an example of an embodiment of a programmable access point, such as access point 110, according to this invention.

In operation, POTS line driver 201 (also referred to as a subscriber line driver) interfaces with the network 101 through a communications interface 211. POTS line driver 201 also interfaces with customer premise equipment 112. As an example, POTS

line driver 201 receives first communication signals from network 101 through communications interface 211 and sends these second communication signals to a customer premise equipment device, such as one of the devices 113-117 illustrated in FIG. 1, for example. The communications interface 211 carries out interfacing operations such as, but not limited to, signal level adjustment and signal timing adjustment on received communications signals. Further to the previous example, the customer premise equipment device can respond by sending a second communication to the access point 110 which is conditioned by communications interface 211 and sent to network 101. Suitable implementations of the POTS line driver 201 are well-known in the art and are not described in further detail. In one embodiment, POTS line driver 201 is programmable and receives and stores at least one operating point (which POTS line driver 201 uses to control the level of its output) from comparator and control logic 203.

POTS line driver 201 also provides the power to connected customer premise equipment 112 along the same communication lines (referred to as customer subscriber lines or subscriber lines) used for the first and second communication signals. As the POTS line driver 201 supplies power to the customer premise equipment along a subscriber line, the electrical load the customer premise equipment 112 presents to the POTS line driver 201 is referred to as the subscriber line load or subscriber line driver load. The power which is provided to the customer premise equipment 112 is provided by the POTS line driver 201 and is supplied to the POTS line driver 201 by the active power supply. The active power supply is whichever of the power supply 206 or the backup power supply 207 which is providing power to POTS line driver 201. Generally, this will be power supply 206. In the case of a failure of power supply 206, the backup power supply 207 is provided to take over the job of supplying power to POTS line driver 201. When the power saving features of the present invention are enabled, the power provided by the POTS line driver 201 to the customer premise equipment 112 is controlled by comparator and control logic block 203.

Sensors 202 sense electrical characteristics on the communications lines coupling the POTS line driver 201 with the customer premise equipment 112. These sensed electrical characteristics are herein referred to as measured values. These measured values may include, but are not limited to, a voltage value and a current value. In an embodiment, the electrical characteristics chosen to be sensed can be any which are indicative of the power usage of the customer premise equipment 112. Sensors 202 provide output signals representative of the sensed electrical characteristics to comparator and control logic block 203. These output signals will vary with many things such as which customer premise equipment devices (e.g. devices 113-117) are attached to the POTS line driver 201, which devices are off-hook (i.e. active), and what modes of operation the devices which are active are in. Suitable implementations of the sensors 202 are well-known in the art, are available "off the shelf", and are therefore not discussed in any further detail.

The comparator and control logic block 203 receives an input sensor signal over connection 208 from power supply 206. The comparator and control logic block 203 also receives a battery capacity sensor signal over connection 209 from backup power supply 207. Collectively, these power supply sensor signals are referred to as power supply status signals and they indicate the operating status of the power supplies. One operating state which is of concern is when power supply 206 is unable to fully supply the power required by POTS line driver 201, a state which is called a low power state. A second operating state of concern is when backup power supply 207 has a low power reserve, a state called a low capacity state. Comparator and control logic block 203 provides operating values to POTS line driver 201. The operating values provided to POTS line driver 201 define the operating point at which the POTS line driver 201 is to operate when delivering power to the customer premises equipment.

The comparator and control logic block 203 controls the current or voltage levels delivered by the POTS line driver 201 to the customer premise equipment. In an embodiment, comparator and control logic block 203 comprises a processing unit

having suitable programming. In an embodiment, comparator and control logic block 203 will control the subscriber line voltage level (also referred to as line driver drive level or drive voltage) as voltage control is a common constant voltage method used by plain old telephone service (POTS) systems. Alternatively, for constant current systems, an embodiment where the comparator and control logic block 203 controls current level or drive current is used. Comparator and control logic block 203 controls the voltage drive level by analyzing the measured values of the electrical characteristics and comparing them against the set point values (also referred to as operating load limits) and previous set point values and calculating new values for the set point values.

An exemplary algorithm by which comparator and control logic block 203 operates to analyze and calculate new set point values is shown in FIGS. 3-6. The algorithm of FIGS. 3-6 may be implemented in hardware, software, or a combination of both.

The problem of inefficient power supply in traditional telecommunications networks can be addressed by dynamically varying the power supply in response to sensor feedback of the actual load conditions. By adapting the power drive level to the actual load on a per access point basis, the overall network power consumption can be optimized to the Least Mean Power (LMP) that is required to provide acceptable service to each access point. Least Mean Power refers to delivering the lowest average power which provides all the operating requirements for the customer premises equipment (CPE) devices attached to the network. Additionally, by adapting the source power on a per access point basis, each access point can be optimized to minimize network power loading and/or to optimize back up battery run times by minimizing the available access point source power.

For discussion purposes, use is made herein of plain old telephone service (POTS) technology to describe an exemplary utilization of the present invention. It is to be understood that this is by way of example only and is not limiting.

In plain old telephone service networks, customers access the network with two lines, historically referred to as the tip and the ring. The tip line has a higher voltage than the ring line. Traditionally, the tip line was held at or around earth ground and the ring line was, in the on-hook situation, maintained at a lower voltage, normally intended to be about -48 volts with respect to the tip line.

Devices on plain old telephone service networks may be connected in parallel or series depending on technology used or other design choices. As discussed previously, in systems in which devices are connected in parallel, power is generally provided by the system is in a constant voltage mode. However, due to technology or system design choices, systems devices are sometimes connected in series and in such cases power is provided in a constant current mode. In either case, a change in the customer premises equipment impedance by either the addition of more devices or by the change in the operating state of existing devices on the network will alter the power sharing balance which had been in effect. This sharing of power across multiple devices will, as the customer premises equipment load increases, result in degraded performance or, in more extreme situations, failure to operate some of the devices. As the standards for the design of customer premises equipment devices allows for wide disparity in operating characteristics, under heightened load conditions some customer premises equipment devices may continue to operate with adequate power although others may fail to operate because they receive insufficient power.

Plain old telephone service networks currently have three basic operating modes with respect to the customer premises equipment devices attached to them: on-hook, off-hook, and ring.

The on-hook mode occurs when all customer premises equipment devices on the line are “off-line” or “hung-up”. In this mode, customer premises equipment devices present a high impedance state to the network and thus draw little or no current through the access point.

The off-hook mode occurs when one or more customer premises equipment devices are no longer in the on-hook mode and present a low impedance state to the network. In the off-hook state, devices will draw loop current from the access point. The magnitude of the loop current drawn by any single device will depend in part on whether the loop is acting as a constant voltage or constant current source.

If the POTS line driver 201 (i.e. the SLIC) is in a constant voltage mode, then each device current will be defined by the following basic relationship:

$$I_{device} = \frac{V_{loop} - I_{devicen} * R_{loop}}{R_{device} + R_{loop}}$$

Wherein:

I_{device} = the current of the device

$I_{devicen}$ = the current of all off-hook devices

R_{device} = the resistance of the device

R_{loop} = the resistance of the loop

V_{loop} = the voltage of the loop

When multiple devices are off-hook, each device will receive the available current up to the capable limit of the voltage source (less loop line resistance and internal source losses). When the loop voltage source approaches its capacity, the loop voltage will decrease due to internal source losses and the device currents will decrease linearly.

If the POTS line driver 201 is in a constant current mode, then each device current will be defined by the relationship:

$$I_{device} = \frac{I_{loop} * R_{parallel\_devices}}{R_{device}}$$

And

$$V_{T-R} = I_{loop} * R_{prallel\_devices}$$

Wherein:

I_{device} = the current of the device

I_{loop} = the current of the loop

R_{device} = the resistance of the device

$R_{parallel\_devices}$ = the resistance of all devices

V_{T-R} = the tip-to-ring voltage

These equations apply in the situation where all devices are attached in parallel. In constant-current mode, the tip to ring voltage becomes a function of the total parallel impedance and the constant current loop set point. As multiple devices go off-hook, the tip to ring voltage will decrease as per Ohm's law because the loop current is limited while the total loop impedance is decreasing.

The ring mode occurs when a ring signal is being presented by the network to one or more customer premises equipment devices.

In either the constant voltage mode or the constant current mode, a corresponding change will occur in the voltage or current of the loop, respectively, as per Ohm's law. These changes can be detected and then compared to either threshold values or specific target levels. If the threshold points or target values are exceeded, the control logic can adjust the POTS line driver 201 programming to either increase or decrease the available power or so as to obtain the optimized tradeoff between power consumption and customer premise equipment performance requirements. An enhancement to the detection of levels and comparison to specific reference values would be to detect a change in current or voltage and respond to a change in state.

The general flow of steps in one embodiment for controlling the drive level of POTS line driver 201 is as follows:

1) Load set point default_values. The set points are used as reference values in determining whether the POTS line driver 201 output is within acceptable limits. The set point default_values are predetermined network-wide values for the set points.

2) Check storage/memory (can be a remote storage/memory) to determine if provisioned set point values exist, and if so, load the provisioned set point values. Provisioned set point values are predetermined access point-specific values for the set points.

3) check storage/memory (can be a remote storage/memory) to determine if the power-saving feature is enabled. If the power-saving feature is enabled, set a power_feature_enabled_flag to true. If the power-saving feature is not enabled, set a power_feature_enabled_flag to false.

4) If the provisioned set point values were loaded, set the variable set_point_values equal to the provisioned set point values, otherwise set the variable set_point_values equal to the set point default_values.

5) Set the variable driver_operating_values equal to set_point_values. The variable driver_operating_values is the value given to the POTS line driver 201 which controls the power output for the POTS line driver 201.

6) Store driver_operating_values to the POTS line driver 201.

7) Read the variables power_source_input_status and backup_capacity. The variable power_source_input_status reports which power supply (e.g. which of the group of main power supply and backup power supply) is supplying power to the POTS line driver (201). The variable backup_capacity reports the capacity remaining in the backup power supply as a fraction of full capacity.

8) When either power_source_input_status indicates the backup power supply is supplying power *or* the backup_capacity equals or is less than a low threshold, set a variable low_power_flag to true.

9) When both the low_power_flag is true *and* a variable power_feature_enabled_flag is true, then both set the variable operating_values equal to a variable minimum_operating_values *and* return to step (6). The variable power_feature_enabled_flag is a flag which indicates whether or not the dynamic power feature of the present invention is enabled or not. The variable minimum_operating_values represents the minimum values for the variable operating_values.

10) Measure the tip-to-ring voltage/current and store in the variable measured_values.

11) When the variable measured_values is less than the variable set_point_values *and* low_power_flag is false *and* power_feature_enabled_flag is true, then increment the variable operating_values.

12) When the variable measured_values is equal to or greater than the variable set_point_values *and* power_feature_enabled_flag is true, then decrement the variable operating_values.

13) Go to step (6).

As can be appreciated, this network includes signaling, sensing, and control elements driving a plurality of access points (e.g. a plain old telephone service tip and ring physical interface) where each access point provides operating power to external load devices (customer premise equipment).

As also can be appreciated, each access point includes a power source (current/voltage) and a line driver with a monitor for actual current/voltage levels, a detection/comparison device, and a control device that can adjust the delivered current/voltage to the access point to minimize the necessary delivered power for proper customer premise equipment operation.

FIG. 3 shows a block diagram of an exemplary algorithm 300 for operation of comparator and control logic 203 in an embodiment. Algorithm 300 provides a more

detailed explanation of an embodiment of the algorithm described just previously herein.

With reference to FIG. 3, the control algorithm 300 starts 302 by initializing 304 certain initial conditions (as described in greater detail later herein with reference to FIG. 4). The control algorithm 300 then stores 306 certain operating values for later reference and use. These operating values can include metrics that define the desired POTS line driver 201 operating point. Next, the control algorithm 300 assesses 308 low power conditions for a corresponding power supply (as described in greater detail below with reference to FIG. 5). Then, the control algorithm 300 makes a decision 310 with respect to whether the active power supply (which can be either in the power supply 206 or the backup power supply 207) is functioning normally. (In one embodiment, the power supply 206 itself receives power from a standard alternating current source; hence a general mode of failure in this case would be a "low-power state." Further to this embodiment, the backup power supply 207 can be a battery. Thus a likely mode of failure for this backup power supply 207 would be a "low capacity state.") The active power supply would be whichever power supply is currently providing power to the POTS line driver 201. The decision 310 regarding functionality of the active power supply can therefore include comparing status information for the presently active power supply against appropriate corresponding predetermined operating ranges. When this decision 310 identifies abnormal power supply status, the algorithm 300 sets 312 the initial operating values to predetermined minimum operating values.

Minimum operating values are operating values which have been predetermined to be the operating values which cause the POTS line driver 201 to provide the minimum useful amount of power to the customer premise equipment. Generally, the minimum operating values provide for power levels which allow for only one or at most, a few, customer premise equipment devices to operate at the same time. Minimum operating values are designed for use only in unusual situations, such as when power supply 206 and backup power supply 207 are both not in normal operating

states. The minimum operating values are generally predetermined by network engineers to be the necessary operating state for the access point given a condition of low power supply capability. After implement minimum operating values block 312, control passes back to the top of store operating values block 306. When it is determined in is power supply in low power state decision block 310 that the active power supply is operating in a normal state, control continues to regular conditions control block 314. Regular conditions control block is described in detail hereinafter in reference to FIG. 6. After regular conditions control block 314, control passes back to store operating values block 306. Thus, in this embodiment, control continually loops.

FIG. 4 shows an exemplary implementation of the initialize block 304 of FIG. 3. The algorithm 300 comes from start indicator 301 (shown in FIG. 3) and loads 402 default set point values from memory or other source such as storage unit 212. Set point values are values which define preset tolerance ranges for the operating point of POTS line driver 201. Set point values are generally defined by network technicians or network operators or the like and represent general values determined for a general access point and generally not specifically for a particular access point. Next, the algorithm 300 checks 404 the memory or storage to determine if provisioned set point values have been set. Provisioned set point values are generally similar to default set point values but are determined for a specific access point after taking into account the specific nature of the access point, the customer premises equipment devices attached thereto, and the operating norms of the customer premises equipment devices.

If provisioned set point values are determined to exist, they are loaded or read 406 and a provisioned flag is set 408 to true. The provisioned flag is a software (or hardware) flag indicating whether provisioned set point values were stored in memory. If provisioned set point values are not found in memory, the algorithm 300 sets 410 the provisioned flag to false. After setting the provisioned flag, memory or storage is read 412 to determined if the power saving feature of the present invention is to be implemented. If the provisioned flag is true, the set point values are set 416 to the

previously read provisioned set point values. Otherwise, if the provisioned flag is false, the set point values are set 418 to the previously read default set point values. Next, the operating values are initialized 420 to the just-determined set point values. Thus, the initialize block 304 is finished and algorithm 300 proceeds to store operating values block 306, shown in FIG. 3.

These various values (default set point values, provisioned set point values, power feature flag, provisioned flag), as a group or in any sub-combination desired, may be stored in memory located remotely on the network, such as in central database 203, or local to the access point 110.

FIG. 5 shows an exemplary algorithm in one embodiment for the low power conditions control block 308 of FIG. 3. This figure shows one method for determining and handling the situation when the active power supply is in a low power state.

In operation, the algorithm 300 continues from the store operating values block 306 of FIG. 3 and reads 502 the active power supply sensor signal (i.e. the input sensor signal on connection 208 when power supply 206 is active or the battery capacity sensor signal on connection 209 when backup power supply 207 is active) is read. The algorithm 300 then checks 504 the active power supply sensor signal against normal power supply operating values to determine whether the active power supply is operating normally or not. If the active power supply is not operating in a normal operating range, the algorithm 300 sets 506 a low power flag to true. The low power flag can be maintained in any available memory such as, but not limited to, ram or more permanent storage. If the active power supply is operating in a normal operating range, the algorithm 300 sets 508 the low power flag to false. After setting the low power flag, the algorithm 300 next continues to block 310 shown in FIG. 3.

The low power flag, as set in either blocks 506 or 508, is used by the algorithm 300 in determining whether to set minimum operating values in block 312 as discussed in reference to FIG. 3 previously herein.

FIG. 6 shows an exemplary algorithm for regular conditions control block 314. This algorithm handles any required adjustment of the operating values in response to measured conditions.

In operation, the algorithm 300 continues from the active power supply in low power state decision block 310 shown in FIG. 3 and reads 602 the signals from sensors 202 representing the electrical characteristics of the POTS line driver 201 output. As previously discussed, these characteristics may be, but are not limited to, such things as the voltage across the output lines of the POTS line driver 201 or the current drawn by the customer premise equipment attached to the output of POTS line driver 201. The algorithm 300 then determines 604 whether the measured values indicate that the output of the POTS line driver 201 is such that the operating values need to be incremented.

There are actually three conditions which must be met before a determination that the operating values must be incremented is made. The first condition is whether the measured values are below the set point values. The second condition is whether the low power flag is false. The third condition is whether the power feature flag is true (i.e. the power saving abilities of the present invention are to be implemented). Only when the measured values are below the set point values, the low power flag is false, and the power feature flag is true is the determination positive. If this is the case, the algorithm 300 increments 606 the operating values. Incrementing of the operating values can take many forms, but in an embodiment, incrementation would take place by the addition of a preset value.

Thereafter, or if the operating values are not to be incremented, the algorithm 300 determines 608 whether the operating values must be decremented. There are two conditions which must be met before a determination that the operating values must be decremented is made. The first condition is whether the measured values are greater than, or equal to, the set point values. The second condition is whether the power feature is true. Only if the measured values are greater than or equal to the set point values and the power feature flag is true is a determination that the operating values

must be decremented made. If this is the case, the operating values are decremented 610. Decrementing of the operating values can take many forms, but in an embodiment, decrementation would take place by the subtraction of a preset value. Thereafter, or if the operating values do not need to be decremented, the algorithm 300 passes out of block 314 and continues to block 306 discussed previously herein in reference to FIG. 3.

The increment and decrement values are, in an embodiment, set by network technicians during the initial setup of an access point, and are considered fixed values. They may be altered or changed by network operators whenever needed to address the average or peak operating conditions of the customer premise equipment devices and the capabilities of the access point change or indicate that revision of the increment and decrement values is necessitated.

This algorithm or its operational equivalents may be used to provide power over networks at a least mean power level. Least mean power level means that the mean (or average) power waste is minimized. By detecting the voltage/current relationship at the access point, it is possible to dynamically adapt the network drive source so as to only provide the power required by the customer premise equipment load at a specific access point during a specific period of time. By adapting the drive level to the actual load on a per access point basis, the overall network power consumption can be optimized to the least mean power that is required to provide acceptable service to each individual access point. Additionally, by adapting the source of power on a per access point basis, each access point can be optimized to minimize network power loading or to optimize back up battery run times by minimizing the available access point source power.

By use of the present invention, power supplies can be minimized to allow the addition of at least one extra device and allow it to work while the system is on backup power. This is because, by setting the operating values to minimum operating values, at least one device is allowed to operate, but the extra power for more devices is saved

thus hopefully allowing operation within the capabilities of a malfunctioning power supply 206 or extending the operation time of a partially drained backup power supply 207 (a battery in one embodiment).

Referring to FIG. 7, shown is a diagram showing an operating limit range.

Shown is an upper operating limit 702, a lower operating limit 704, an A region 706, a B region 708, and a C region 710.

Together, the upper operating limit 702 and the lower operating limit 704 comprise operating limits, or an operating limit range, for the output of POTS line driver 201. Specifically, comparator and control logic block 203 uses the operating range in comparing the measured values output by sensors 202 in deciding whether new values for the set points or operating values are required. If the measured values fall in range A 706, then the measured values are too high (indicating that the subscriber line load of the customer premise equipment has fallen), and thus the operating values are decremented by algorithm 300. Similarly, if the measured values fall in region C 710, the measured values are to low indicating that the load has increased, and so the line driver operating values are increased by algorithm 300. If the measured values fall in region B 708, no change in the operating values is required.

Regarding FIG. 8, shown is an alternative method of evaluating the measured values referred to as a step increment test.

Shown is a previous value 802, a previous value + delta 804, a previous value - delta 806, a D region 808, an E region 810, an F region 812, and a G region 814.

In operation, the step increment test is based on a previous value of the measured values shown here as previous value 802. When the operational status of the customer premise equipment changes by a single increment (i.e. a single device changes state such as going into operation or ceasing operation), this alters the subscriber line load seen by POTS line driver 201. While this change will be different depending on the device and change which occurred, the change detected by sensors 202 will generally be in the same range regardless of device or the nature of the change. Thus,

by calculating the previous value 802 plus a delta value (also called a change value or incremental value) this gives previous value + delta 804 which is used as an upper threshold or upper operational limit. Similarly, by calculating the previous value 802 minus a delta value (also called a change value or incremental value) this gives previous value - delta 804 which is used as a lower threshold or lower operational limit. Thus, if the measured values fall in region D 808, then comparator and control logic 203 determines that at least one device has been added to operation and thus the operating values need to be incremented. Similarly, if the measured values fall in region G 814, then comparator and control logic 203 determines that at least one device has been removed from operation and thus the operating values need to be decremented. If the measured values fall in regions E 810 or F 812, then the threshold of change has not been met so no change in the operating values is needed.

It is noted that the embodiments discussed and implied can be applied not only to control the direct current (DC) outputs (such as the dc bias powering attached equipment) of the POTS line driver 201, but can also be applied to control any alternating current (AC) outputs (such as the communications signals presented to the attached equipment) of the POTS line driver 201. In one embodiment for controlling communications signals, a mean value for the magnitude of the communications signal is determined and compared against frequency set point values in determining the frequency signals operating points.

It is noted that the method embodiments discussed and implied can be implemented in hardware or software running on hardware examples of which are embedded processors or stand-alone personal computers. It is noted also that the method embodiments discussed and implied can be implemented on computer readable mediums such as, but not limited to, optical, punched, or magnetic tape, optical, punched, or magnetic cards, floppy disks, compact discs (including compact disc read only memories or CD-ROMs), digital versatile discs or DVDs (including digital

versatile disc read-only memories or DVD-ROMs), pre-programmed chips (such as pre-programmed flash memories, read-only memories or ROMs, etc.), and harddrives.

While the power saving features of the present invention are generally most effective for networks having an off-hook condition, it is noted that the benefits of the present invention may also be effective on networks in an on-hook mode or ring mode.

While this reference description is specific for analog plain old telephone services access networks, the invention can be applied in any system where power consumption is critical and where the load variations can be sensed and the power source can be dynamically adjusted. Additionally, the present invention may be implemented in hardware-only configurations and in hardware plus software configurations.

The advantages of the present invention include, but are not limited to:

1) The minimization of power consumption through dynamic adjustment of the voltage/current relationship so as to maintain adequate power to allow proper customer premise equipment operation without providing excess power when line conditions do not warrant fixed power levels. This allows network designers to avoid the traditional tendency to design "overpowered" networks in attempts to cover all possible customer premise equipment loading. The dynamic adjustment of power provided also permits continued use of legacy equipment with their concomitant higher operating levels. The minimization of power consumption also has the benefit of maximizing access unit operation when running off of backup power supplies such as batteries which have limited capacity. This maximization of backup power operation also can benefit so called "lifeline" services such as telephone access during power outages.

2) The adjustment of the available drive level for power control based on threshold target values.

3) The adjustment of the available drive level for power control based on limit values.

4) The adjustment of the available drive level for power control based on voltage/current changes (allowing identification of secondary devices going off-hook).

5) The capability to set the threshold, limit, or state change values remotely so that further system or customer specific optimization can be achieved.

6) The detection of the loss of main input power and the adjustment of the loop current for a minimum current level to extend the ability to support at least one device while operating on back up power (such as from a battery).

7) The detection of decreasing capacity of the power source and reduction of the loop current to a minimum level to extend the ability to support at least one device.

8) The capability to enable or disable the lowest mean power algorithm and revert to a fixed level operation.

9) The automatic adjustment of power provision also minimizes service provider technical support requirements, lowers service provider operating costs, and enhances the level of service and therefore, customer satisfaction, felt by end users.

The present invention has been described in terms of preferred embodiments, however, it is understood that numerous additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made of the general inventive concept without departing from the spirit or scope of the appended claims and their equivalents.